The AIRES Far-Infrared Detector Array

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A unique, state-of-the-art array of detectors is being developed as part of AIRES, the airborne infrared echelle spectrometer for SOFIA (the Stratospheric Observatory for Infrared Astronomy). SOFIA is a Boeing 747 that will carry a 2.7-meter telescope to operating altitudes up to 45,000 feet. It is under development by NASA and the DLR (the German aerospace center). SOFIA is scheduled to begin operations at Ames Research Center in late 2004. AIRES—which is being built at Ames—is the facility spectrometer for SOFIA; it will measure atomic and molecular spectral lines at far-infrared wavelengths, approximately 30 to 400 times the wavelengths of visible light, to probe physical characteristics of astronomical sources such as star-forming regions and our galactic center.

Highlights of the AIRES detector development include the following: Infrared light collected by the SOFIA telescope will be distributed by the optical system of AIRES to its semiconductor detectors so as to permit simultaneous separation of different wavelengths in each of 24 imaging picture elements (pixels) viewing the sky. The detectors will be arranged in a 16 x 24 rectangular grid with pixels spaced eight-hundredths of an inch apart. Each detector is a chip of antimony-doped germanium mounted in an integrating cavity and fed with light from the spectrometer by a conical light collector, shown in figure 1.

The AIRES optical system and detector assembly will be cooled in a cryostat to a few degrees kelvin, as required to achieve the highest possible sensitivity to the infrared radiation collected by the SOFIA telescope. The detectors convert the light from the spectrometer into electrical signals, which are amplified and multiplexed by adjacent integrated circuits that route the signals to the data system outside the cryostat.

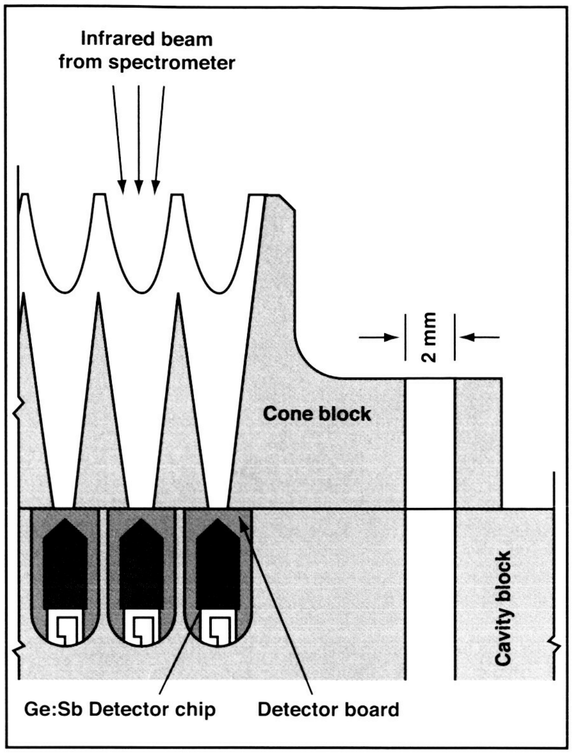

Fig. 1. Detail of the AIRES far-infrared detector geometry.

These unique multiplexing amplifiers were designed specifically for AIRES by industrial specialists collaborating with AIRES team members. The device technology was originally developed for the Space Infrared Telescope Facility, but the new circuits are tailored for the wider range of infrared backgrounds expected on SOFIA. They feature externally programmable gains to accommodate different observing conditions, and so will be suitable for a variety of SOFIA instruments as well as some spaceborne instruments. The AIRES team pioneered this development, and has tested several devices, confirming that their cryogenic noise and gain performance meets AIRES needs.

The entire detector package—detectors, amplifiers, and array assembly—is custom designed and built, with much of the work done at Ames by the AIRES team. In previous tests, the detector configuration sketched in figure 1 was shown to work well. During FY00, testing of the amplifiers and design and fabrication of a 2 x 24 protoflight detector module have made great progress. This unique detector system, essential for the success of AIRES, is well on its way to achieving its design performance.

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The World's Largest Grating

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The airborne infrared echelle spectrometer (AIRES) is a high-resolution grating spectrometer under development as a facility science instrument for the Stratospheric Observatory for Infrared Astronomy (SOFIA). An echelle is a grating used at a steep angle of incidence relative to the incoming light beam. The spectral resolution of a grating spectrometer is directly proportional to the projected length of its grating along this beam and inversely proportional to the wavelength of light being analyzed. AIRES is designed to measure far-infrared (long-wavelength) spectral lines of molecules and atoms originating in the interstellar medium. Therefore, AIRES requires a grating significantly longer than any previously made. In fact, the wavelength range and resolution planned for AIRES demands the world's largest grating!

Further, the entire AIRES optical system must be operated at a few degrees kelvin (near absolute zero). To minimize problems associated with thermal contraction in this cryogenic environment, to facilitate diamond machining, and to ensure long-term stability, a monolithic aluminum blank was chosen. This blank was manufactured from 152-millimeter (mm)-thick, aluminum alloy 6061-T651, Type 200 tooling plate. The final blank is 102 mm thick, 267 mm wide, and 1067 mm long with the corners removed to provide a near-elliptical planform. The blank was light-weighted by cutting triangular-shaped slots with a wire-electric-discharge machine, which builds less stress into the blank than conventional milling and has the ability to cut deep slots with small corner radii. The resulting truss-like structure is symmetric, provides good specific stiffness, and is 70%-light weighted. Before final machining, the blank was heat-treated at 375 degrees Centigrade (°C) for 2 hours and then thermally cycled 7 times between –200°C and 100°C to obtain the required stability.

A groove spacing of 980 microns, an apex angle of 90 degrees, and a blaze angle of 76 degrees were selected to optimize the packaging and optical performance of the grating at the wavelengths of interest. This combination of parameters maximizes the spectral resolution for the 63- and 145-micron neutral oxygen, 157-micron singly ionized carbon, and 205-micron singly ionized nitrogen transitions arising from the interstellar medium, without adversely affecting performance for other high-priority transitions.

The grating was ruled under contract with Hyperfine, Incorporated, of Boulder, Colorado, with a fly cutter using a single-point diamond turning on a custom ruling engine. The completed grating is shown in figure 1. The light-weighting truss structure is evident along its